

# A CORRELATION BETWEEN SOLAR RADIATION INTENSITIES AND RELATIVE HUMIDITIES

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In the compilation of data on two synchronous studies of factors affecting tree growth and of weather and forest fire fuel relationships<sup>1</sup> a noteworthy relation between relative humidity and solar radiation intensity was discovered.<sup>2</sup> This relationship is not advanced to supplant other indices for the computation of probable radiation intensities, such as have been used with success by Kimball (6). It is advanced as a contribution to research on the relations between weather and ecological problems and forest fire-hazard studies in which are stressed short period information for all kinds of meteorological conditions including all degrees of cloudiness.

The solar radiation record was obtained by a spherical hot-junction thermopile devised by the writer (2) (3) to integrate all radiation at normal incidence. For the work here reported three of these thermopiles (type A(3)) in series were registered on an Engelhard RM recorder (4) giving 30 readings an hour. This material has been grouped in correlation tables which differ in the relative humidity data employed and the number of observations included. All the material available has been used; that the total hours do not equal all those possible is due to the absence of the observer on rainy days when the fire hazard was nil.

The crude data are presented in Table 1. In August and September, 1927, 172 three-hour records out of a possible 183 were obtained, so that a variety of sky conditions are represented. The gram calories per square centimeter for the 3-hour period are correlated with the relative humidity (by sling psychrometer) at the end of that period. The 8-11 a. m. (apparent time) radiation values are used with the 11 a. m. relative humidity (per cent), the 11 a. m.-2 p. m. radiation with the 2 p. m. relative humidity, the 2-5 p. m. radiation with the 5 p. m. relative humidity. From these data (correlation coefficient  $r = -0.76$ ) may be calculated the regression equation of solar radiation on the relative humidity.

Solar radiation ( $\sigma = \pm 36.85$ ) =  $306.0 - (2.678 \times \text{relative humidity (in per cent)})$ . The standard error  $\sigma$  includes two-thirds the readings.

From similar data for July 1 to August 20, 1926, inclusive, 141 periods, out of a possible 153 (see table 2), the following relation is obtained ( $r = -0.75$ ):

<sup>1</sup> These studies were common projects of the Northeastern Forest Experiment Station and the Harvard Forest. The meteorological data, other than solar radiation, were obtained by Mr. P. W. Stickel, in charge, and Mr. A. W. Gottlieb; planimeter records of solar radiation by Mr. Gottlieb; computations by Mr. Roy A. Chapman.

<sup>2</sup> There are certain well-known factors controlling the intensity of solar radiation at a given time and place, as follows:

- (1) The distance of the earth from the sun.
- (2) The zenith distance of the sun.
- (3) The scattering of the solar rays by the gas molecules of the atmosphere, including water vapor.
- (4) The selective absorption of solar rays by atmospheric gases, principally by water vapor.
- (5) The scattering and absorption by atmospheric dust.
- (6) The reflection from the upper surfaces of clouds.

The law of variation of each of these factors is well known, and the important factors are solar zenith distance, the water-vapor content of the atmosphere, which is determined through the absolute humidity, the dust content of the atmosphere, and the percentage of the sky covered with cloud.

It seems to be a coincidence that a high minus correlation exists between the relative humidity of the atmosphere and radiation intensity. With a clear sky the relative humidity generally decreases rapidly as the air temperature rises to its maximum for the day, and at approximately the same time the radiation intensity increases as the zenith distance of the sun decreases. Furthermore, the probability of the formation of lower clouds increases as the relative humidity increases and such clouds act as a reflector to turn back the incoming solar radiation. It thus appears that the relative humidity, which is an important factor in forest-fire hazard also gives an indication of the solar radiation intensity; but as the author points out, it can hardly be employed in computations of solar radiation intensity at a given time and place.—H. H. K.

Solar radiation ( $\sigma = \pm 41.63$ ) =  $306.1 - (2.635 \times \text{relative humidity (per cent)})$ .

There is a loss in intensity of radiation due to the increasing air mass through which it must pass as the zenith hour angle of the sun increases. (Kimball (5) and (6).) No allowance for this factor entered into the values of the radiation used above. The need for such a correction can be reduced by retaining only the 11 a. m. (8-11) and 2 p. m. (11-2) periods. A further correction was made by substituting the average of the 11 a. m. and 2 p. m. relative humidity values for the single 2 p. m. relative humidity reading employed heretofore. In this way was obtained (table not given) a correlation coefficient  $r = -0.80$  and the regression equation:

Solar radiation ( $\sigma = \pm 30.93$ ) =  $311.4 - (2.543 \times \text{relative humidity (per cent)})$ .

The estimate of relative humidity used above may be further refined by checking the 11 a. m. and 2 p. m. readings of the hair hygrograph with the sling psychrometer and then estimating the integrated deviation of the trace. This deviation was applied to the average relative humidity. These values are entered in a diagram (Table 3). An  $r = -0.84$  is obtained, and a regression equation.

Solar radiation ( $\sigma = \pm 29.02$ ) =  $303.2 - (2.530 \times \text{relative humidity (per cent)})$ .

These two successive refinements, first, the correction for loss by absorption in increasing air mass, and second, the improvement in the value of relative humidity, show about the same improvement, 0.04, in the value of the correlation coefficient. The standard error is diminished 20 per cent by the isolation of values with a small variation in air-mass absorption.

Comparison of the correlation table (No. 3) for solar radiation and relative humidity ( $r = -0.84$ ) with the correlation table (No. 4) for solar radiation and vapor pressure ( $r = -0.31$ ) shows how large a factor is the atmospheric transmission. For it is by the association of the atmospheric temperature with the absolute atmospheric moisture that the resultant, the relative humidity, becomes significant when clear skies do not prevail.

For a check, the hair hygrograph record was planimetered for the average relative humidity between 8 a. m. and 5 p. m. for each day of August and September, 1927. The total solar radiations for the same 9-hour periods were computed and entered with them. (Table 5.) The calculations give the following ( $r = -0.887$ ):

Solar radiation ( $\sigma = \pm 71.4$ ) =  $875.2 - (7.60 \times \text{relative humidity (per cent)})$ .

Over the longer period of time and by use of a relative humidity value which is probably more accurate, a very good value for the correlation coefficient is obtained.

That cloudiness reduces the duration of sunshine is a commonplace daily observation. In the absence of clouds variation in vapor pressure is correlated with minor fluctuations in the radiation intensities. An empirical formula introducing the mean cloudiness was used by Kimball (6) to reduce the clear sky intensities to mean intensities. (See Ångström (1).)

The correlation values here derived for insolation intensities and relative humidity imply that some relation must exist between mean relative humidity and mean cloudiness for these periods. The writer has not been able to obtain data which could be examined for such a relation. That such a relationship is tacitly admitted, at least qualitatively, is apparent from the monthly discussions in the review of relative humidity and sunshine in the weather elements under the caption Weather in the United States.

If the quantitative relation here discussed is found to hold generally it will be useful in various sorts of ecological work. It will make possible the approximation of regional sunshine values for which observations on the mean cloudiness are not available. For public-health work the study of the relation of relative humidity to loss of radiation in the ultra-violet "biological band" is even more striking, as evidenced by some determinations (unpublished) of the writer.

## LITERATURE CITED

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TABLE 1.—Solar radiation for 3-hour period correlated with per cent relative humidity at end of period, August 1 to September 30, 1927

[Three-hour periods are 8 to 11 a. m., 11 a. m. to 2 p. m., 2 to 5 p. m.]

Solar radiation, gr.=cal./cm. <sup>2</sup> . (3-hour periods)	Relative humidity (per cent)							Total
	100-90	89-80	79-70	69-60	59-50	49-40	39-30	
213-237					4	2	1	7
188-212		1			7	7		15
163-187		1	4	3	20	9		37
138-162			7	5	13	2	1	28
113-137	1	3	5	4	7	1	1	22
88-112	2	2	9	8	4			25
63-87		3	3	1				7
38-62	4	2	5	1				12
13-37	13	5	1					19
Total								172

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TABLE 2.—Solar radiation for 3-hour periods correlated with per cent relative humidity at end of period, July 1 to August 20, 1926

[Three-hour periods are 8 to 11 a. m., 11 a. m. to 2 p. m., 2 to 5 p. m.]

Solar radiation, gr.=cal./cm. <sup>2</sup> . (3-hour periods)	Relative humidity (per cent)							Total
	100-90	89-80	79-70	69-60	59-50	49-40	39-30	
213-237					2	18	12	32
188-212				4	5	5	3	17
163-187			2	4	7	6		19
138-162			3	5	6	1	1	16
113-137	2		3	4	2	3		14
88-112	1	1	4	3	2	3	1	15
63-87	2	3	4	1	1			11
38-62	4	3			2			9
13-37	4	2		2				8
Total								141

TABLE 3.—Solar radiation for the midday 3-hour period, 11 a. m. to 2 p. m., correlated with the relative humidity for the period determined from hygrograph record, August 1 to September 30, 1927

Solar radiation, gr.=cal./cm. <sup>2</sup> . (3-hour periods)	Relative humidity (per cent)							Total
	100-90	89-80	79-70	69-60	59-50	49-40	39-30	
225-249						1		1
200-224						2	2	4
175-199					9	7	1	17
150-174				5	4	4		13
125-149		2	1					3
100-124	2		2	1	3			8
75-99	1	1	3					5
50-74								0
25-49	2	3						5
0-24	1							1
Total								57

TABLE 4.—Solar radiation for the midday 3-hour period, 11 a. m. to 2 p. m., correlated with the vapor pressure for the period determined from hygrothermograph record, August 1 to September 30, 1927

[Compare with Table 3]

Solar radiation, gr.=cal./cm. <sup>2</sup> . (3-hour periods)	Vapor pressure										Total
	0.749-0.700	0.699-0.650	0.649-0.600	0.599-0.550	0.549-0.500	0.499-0.450	0.449-0.400	0.399-0.350	0.349-0.300	0.299-0.250	
225-249									1		1
200-224							2			2	4
175-199				2			4	5	4	2	17
150-174	1		1	3	2	2	1	2	1		13
125-149				1	1		1				3
100-124	1			1	1	2	2			1	8
75-99				2			1	2			5
50-74											0
25-49	1			1		1	1		1		5
0-24								1			1
Total											57

TABLE 5.—Solar radiation for the 9-hour period, 8 a. m. to 5 p. m., correlated with per cent relative humidity from integrated hygrograph record for period, August 1 to September 30, 1927

Solar radiation, gr.=cal./cm. <sup>2</sup> . (9-hour periods)	Relative humidity (per cent)							Total
	100-90	89-80	79-70	69-60	59-50	49-40	39-30	
578-640					1	3	2	6
515-577					1	7	2	10
452-514				4	6	2		12
389-451				3	2	1		6
326-388		1	3	1		1		6
263-325			4	1	2			7
200-262		1	3	2				6
147-199		3						3
84-146		2	2					4
21-83		1						1
Total								61